CHAPTER 9

WELL DRILLING SUPERVISOR

The Naval Facilities Engineering Command (NAVFAC) invests millions of dollars in water well drilling equipment and the training required to enable the Naval Construction Force (NCF) to meet water well drilling requirements at various locations and conditions throughout the world.

The COMSECOND/COMTHIRD Naval Construction Brigades require all Naval Mobile Construction Battalions to maintain an allowance of personnel qualified in water well drilling operations. The Naval Construction Training Centers (NCTC) and Regiments from both Gulfport, Mississippi, and Port Hueneme, California, provide training in water Well drilling operations. The NEC for water well driller is 5707. The means of attaining this NEC is most often through completion of the water well driller course that is offered at NCTC, Port Hueneme, California.

This chapter can only provide the basic terminology and procedures used in well drilling operations. The extensive knowledge and skills required to perform as an effective well drilling supervisor must be gained through formal training and on-job-training experience.

WELL DRILLING SUPERVISOR RESPONSIBILITIES

Successful well drilling operations are a direct result of the efficiency of the supervisor and crew. The drilling rig and its controls are not complicated and can be mastered in a short time; however, knowledge of the mechanical operations is only the start and experience is the vital element.

Drilling water wells is an art for which there are no hard-and-fast rules; it is an art that requires a good deal of common sense and improvisation. The well drilling supervisor must have a general knowledge of the physical structure of the earth's crust and the groundwater resources within. Often, problems arise in well drilling, and the well drill supervisor must be able to visualize what is occurring at the bottom of the hole. An awareness of the conditions under which groundwater occurs and of geologic conditions is a shortcut to the solution of some drilling problems that would otherwise take much time and experience to attain through the trial-and-error method.

WATER SOURCES

The source of all fresh water upon and in the land areas of the earth is the oceans. Precipitation in the form of rain, hail, sleet, or snow recharges lakes, streams, and underground water. Part of the precipitation that falls upon land areas soaks into the ground and under the influence of gravity is pulled downward until it becomes part of the *saturated zone.* Water in the *saturated zone* is referred to as *groundwater* and it is within this zone that wells are developed. Water recovered from beneath the ground accounts for a much larger percentage of our water supply than that from natural lakes or man-made reservoirs.

Above the *saturated zone* is a zone identified as the zone *of aeration.* This zone is divided into three belts: (1) the belt of soil moisture or plant root zone, (2) the intermediate belt, and (3) the capillary fringe. Neither the intermediate belt nor the capillary fringe is capable of producing water in usable quantities because the pores or open spaces between individual particles are not all filled with water. Water in the zone *of aeration is* called *subsurface water* and should not be confused with *groundwater* contained in the saturated zone where all the pores are filled with water (fig. 9-1).

The volume of water contained in the *saturated zone* is the total volume of the openings in rocks or between the individual grains of sand or gravel. These openings are referred to as the *porosity of the particular material.*

The physical characteristics of the *zone of saturation* can vary widely, depending upon the geologic formations of the earth layers; that is, sand, gravel, clay, rock, or a combination of these. This zone may also wary in depth from a few feet to many hundreds of feet.

Water may be found within the *saturation zone* in one continuous body or in alternating layers of clay and sand. This all depends on the *impermeability* or the *permeability* of the formations within the *saturation zone;* for example, while clay may hold a relatively high volume of water, the openings between the individual particles are so small that they prevent the flow of water. Clay is then said to be *impermeable.* Confined between

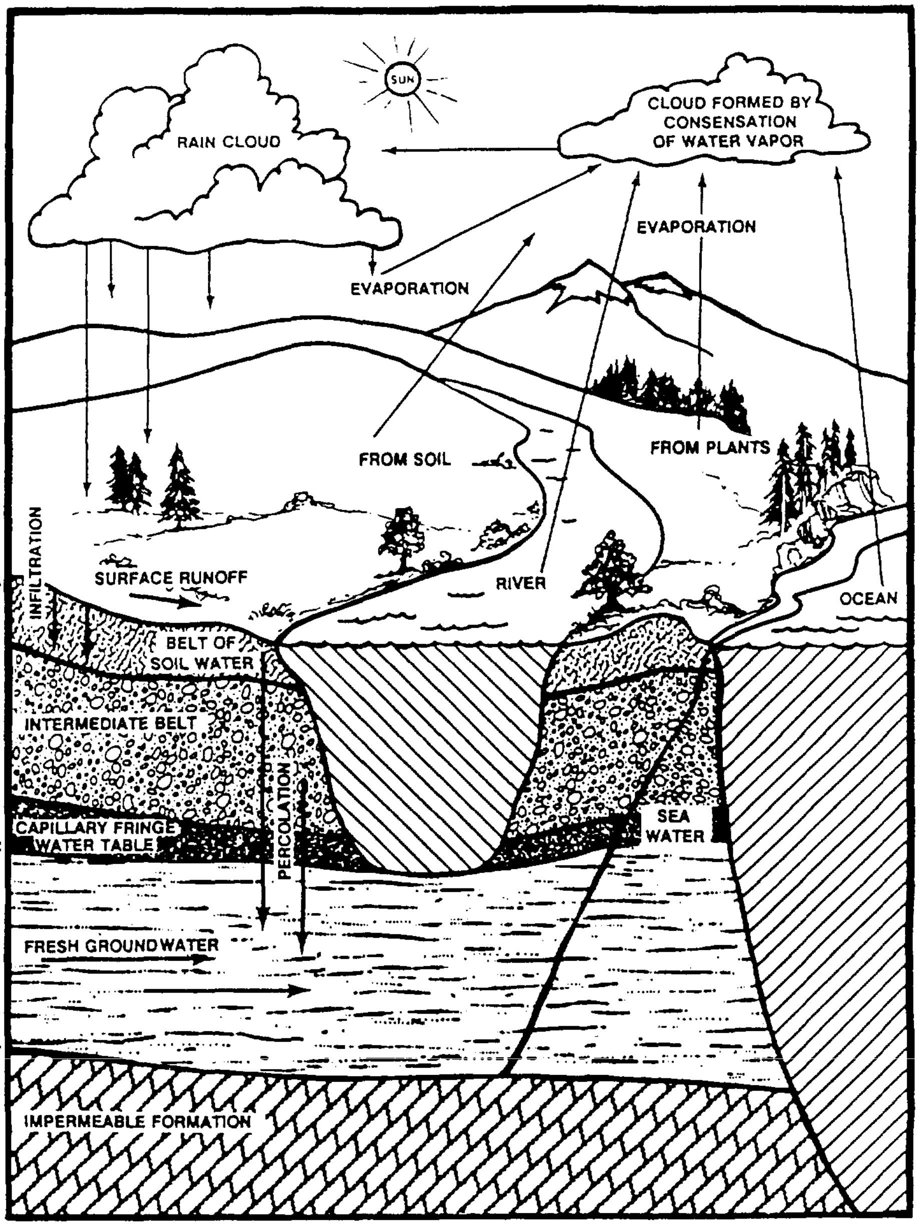


Figure 9-1.–Hydrologic cycle and zone.

two layers of clay maybe a layer of sand which is both *porous* (holds water) and is *permeable* (allows the water to flow). (See fig. 9-2).

A *porous* and *permeable* formation that can yield water in usable quantities is called an *aquifer* (fig. 9-3). If an *aquifer* is not confined by an *impermeable* layer above it, the *aquifer is* said to be under water table conditions and is subjectcd to atmospheric pressure. If an *aquifer* is confined both above and below and the recharge area or source of water is higher than the point where a well is to be located, the water will be under greater than atmospheric pressure and will rise to some point above the water table. When the pressure is sufficient, the well may be free flowing. An aquifer(fig. 9-3) under this condition is called an *artesian*.

Sedimentary, igneous, and metamorphic rock formations are potential sources of water. *Sedimental rocks* are the most common *aquifers*. They are formed by the accumulation of sediments that have been deposited by water, wind, or ice. Limestone is an example of a sedimentary rock and is formed from the accumulation of chemical compounds and minerals that settle together out of water. Water percolating through cracks and joints in a dense limestone deposit results in underground streams and lakes. Throughout thick, nearly horizontal layers of limestone, as well as shale

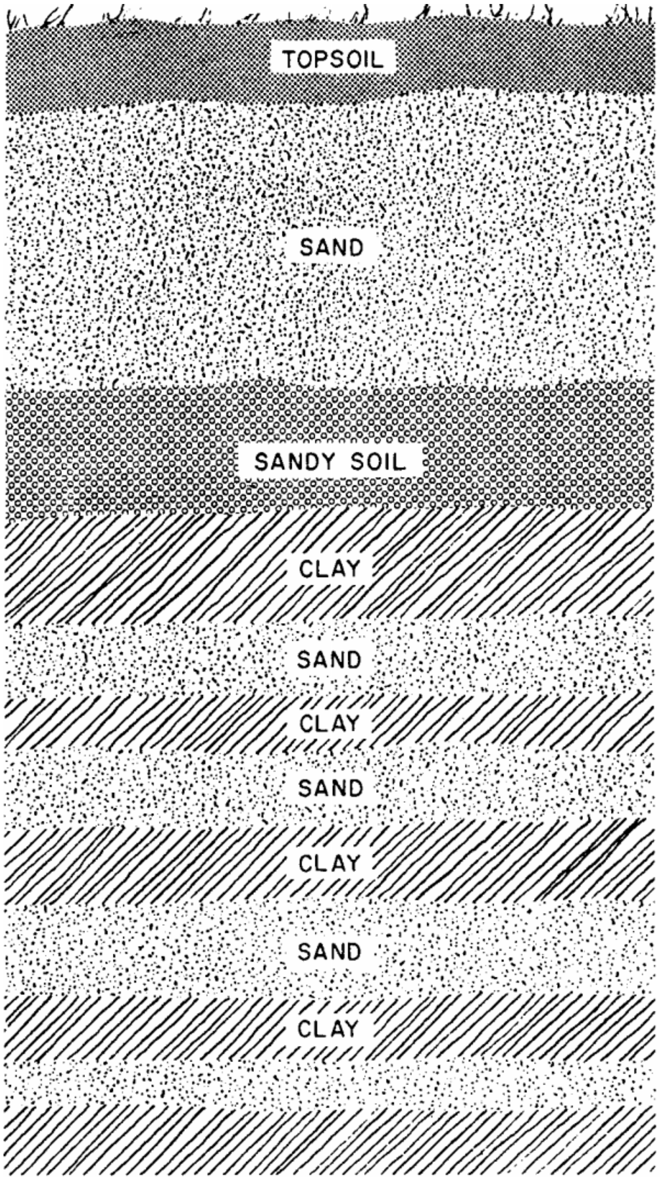


Figure 9-2.-Geologic formation of earth layers.

and sandstone, are huge reservoirs of groundwater. *Sedimentary rock* formations are among the most common and productive of all aquifers, and when found in sandy or gravel formations are easy to drill.

Igneous and *metamorphic formations* are both viewed as a group of hard, dense rocks. Unless highly fractured and occurring close to the earth's surface, they contain far less water than *sedimentary rocks.* The recovery of water from solid rock depends on the existence of many cracks, fissures, or crevices in the rock. Extremely fine deposits of sedimentary materials usually produce little water. Although *highly porous,* they are relatively *impermeable.*

Topographical features created by water action offer an excellent chance for the recovery of groundwater at relatively shallow depths. *Alluvial sedimentary* deposits are the most productive formations for groundwater. The word *alluvial* means deposited by water. Such features include the following: *alluvial valleys* that are rather extensive in area and are the sites of ancient rivers or the flood plains of active rivers; *alluvial fans* that are an accumulation of sediments at the base of mountains, deposited where drainage streams fan out; and *alluvial basins* that are essentially structural troughs created by a rim of mountains and glacial outwash.

GROUNDWATER EXPLORATION

Where extensive groundwater exploration has not occurred, maps, official documents, unofficial documents, and native experience must be used to obtain a fairly reliable indication as to a groundwater

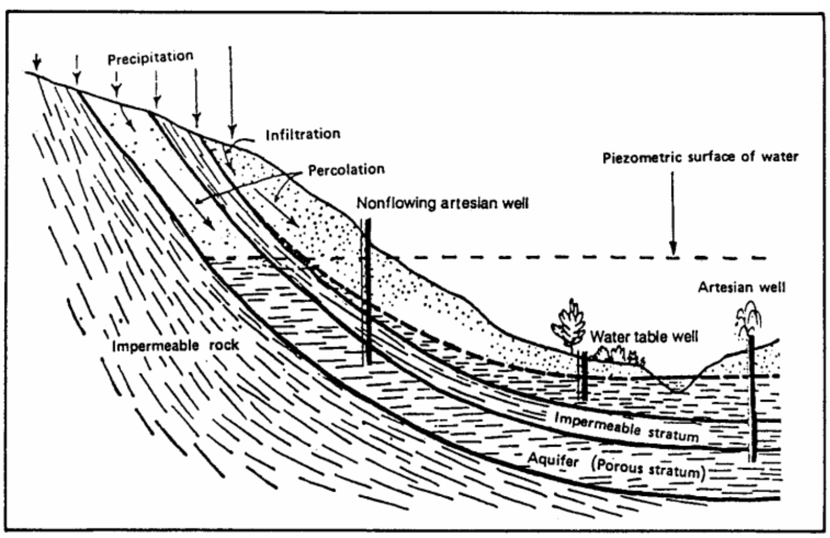


Figure 9-3.—Types of aquifers.

resource of a particular area. The information available normally will give you an idea as to the geological conditions, such as terrain and type material, approximate depth of an *aquifer* or series of *aquifers,* quantities of water that may be expected during different seasons of the year, average depth of the water table, and drilling procedures and problems that may be encountered.

Access to maps and publications is usually through hydrographic offices either on a state or national level, offices of the United States Coast and Geodetic Survey, or its equivalent in other countries, geological or university archives, battalion engineering offices, or native drillers.

When very little is known about the water resources in a particular area, the most valuable clues may come from an inspection of the outcropping of rock format ions. You may need to verify your conclusions by *exploratory drilling,* which is the surest way to establish the existence of water-bearing formations.

Exploratory drilling is usually initiated as part of the groundwater study of an area before construction of water wells at a particular site.

WELLS

Wells are classified into five methods of construction. The methods are as follows: *dug, bored, jetted, driven, and drilled wells,* Each type of well has certain advantages and limitations; and the type of well to be developed depends upon the ease of construction, storage, capacity, limitations as to formations it can penetrate, and ease of safeguarding it against pollution.

A *dug well* is one in which the excavation is Made by the use of picks, shovels, spades, or digging equipment, such as sand buckets or clamshell buckets.

A *bored well is* one in which the excavation is made by the use of hand or power augers.

A *jetted well* is one in which the excavation is made by the use of a high-velocity jet of water.

A *driven well* is one which is constructed by driving a pointed screen, referred to as a drive point, into the ground. Casings or lengths of pipes are attached to the drive point as it is being driven into the ground.

Dug, bored, jetted, and driven wells are relatively shallow, Generally, they are less than 100 feet deep and may be constructed with hand tools. *Drilled* wells in the NCF are normally drilled to the depth of 1,500 feet and are constructed with portable well drilling machines.

ROTARY DRILLING

When using a hand drill to bore a hole, you press the cutting tool or bit into the material to be bored. The material is cut as you turn the bit by means of the drill handle. During the drilling process, chips of the cut material are carried to the top of the hole by the flutes of the bit. A *rotary drilling rig* operates on the same principle, except for the method of raising the cut material, This material is washed to the surface by a fluid substance instead of being carried by the bit itself. The bit of a *rotary drilling rig* is attached to the lower end of the drill pipe.

The methods of drilling for water are referred to as *rotary mud or rotary air drilling. Rotary mud drilling* is currently the most common method used to drill wells and is used where ground formations are loose and unconsolidated. *Mud drilling* is also used in consolidated formations but is not very efficient. The *rotary air drilling* method is preferred when ground formations are consolidated. A limitation of the ***air** drilling* method is the cfm output of the air compressor.

When *rotary mud* or *rotary air drilling* operations are being conducted and a formation that is hard to penetrate is encountered, the *down-hole-drilling hammer* attachment can be used. The *down-hole-drilling hammer* attaches to the lower end of the drill pipe and rotates as well as hammers (short rapid blows) against the hard formation (fig. 9-4). To use the

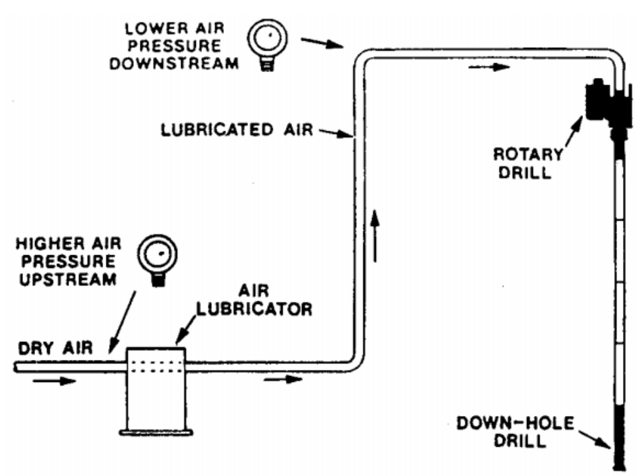


Figure 9-4.-Down-hole-drilling (DHD).

down-hole-drilling hammer, you must *"trip-out"* all the drilled steel and flush all the mud and foreign material before connecting the hammer. Air from an air compressor passes through the string of drill steel and exits out the *down-hole-drilling hammer bit.* This air cleans the cuttings from the bit and carries the cuttings to the surface.

Regardless of the drilling method performed, the objectives of drilling are to

1. identify and locate the site of each test hole,
2. maintain a log of formations penetrated and representative samples obtained,
3. determine the depth to each water level and obtain samples of water from aquifers.

A *Driller's Log,* or *well log,* (fig. 9-5) is used to record an accurate record of the depth and changes in formation along with a description of the samples-taken every 5 feet or at every formation change. Also recorded is a description of the drilling action that is a valuable clue to a change in formation; for example, with the *rotary method,* drilling action in clay or shale is smooth. Chattering of the bit is an indication of sand or gravel.

DRILLER'S LOG

DATE: WELL NUMBER

LOCATION COUNTRY STATE

DRILLED BY CLASS NUMBER

HOLE SIZE BIT SIZE COLLARS

TOWER	HOUR	DATE	FORMATION	DEPTH	VISC

SHEET NUMBER ________ OF ________

Figure 9-5.-Driller's Log.

Smooth drilling, but rapid penetration, indicates fine sand. Additionally, the log includes information of the time it took to drill each foot. As drilling speed is largely determined by the composition of the formations, information from the well log may be used in graph form to reveal the top, bottom, and thickness of each formation. Clues to the composition of each formation are provided by this log and verified by the samples obtained.

Rotary Drilling Crew

The water well rig is normally operated by a *tool pusher, a driller, a derrick hand, and a floor hand.* For expediency, water well drilling as performed in the NCF is a continuous operation; therefore, you are required to have more than one shift. The hours of each shift depends upon the crew size available, the experience level of the members of the crew, and the condition of the equipment; for example, two 12 hour shifts or three 8 hour shifts.

The *tool pusher* is responsible for outlining the overall drilling program and seeing that it is carried out. The *driller* carries out the drilling orders, operates the rig, and must know the depth, viscosity, density, sand content, type of cuttings, number of steel, and the psi of the mud pump. The *derrick hand* works in the mast and

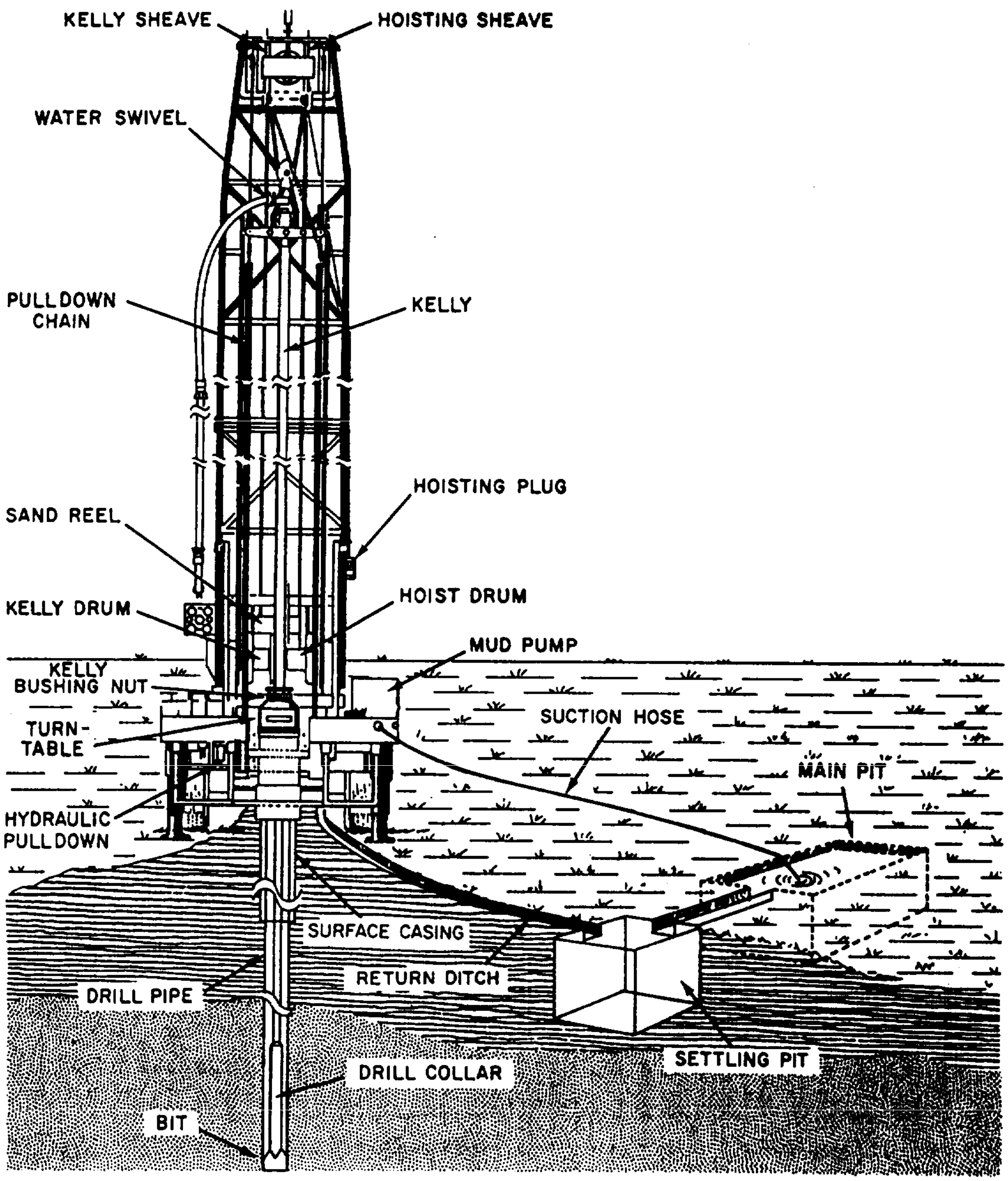


Figure 9-6.-Kelly-drive rotary method of drilling.

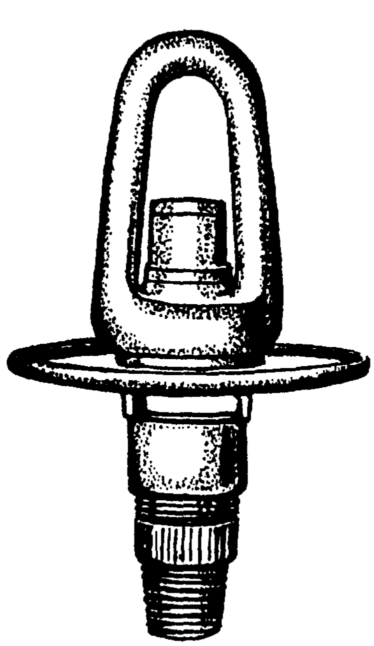


Figure 9-7.-Hoisting plug.

performs tasks, such as racking the steel pipe, screwing the hoisting plug, and handling the drill pipe or casing. The *floor hand* records the information on the drill log, records cutting samples, maintains the mud pits, and maintains all work tools and equipment on the deck of the rig.

All crew members must wear protective clothing or equipment, such as hardhats, gloves, safety shoes, and safety belts. When wearing hard hats, the *derrick hand* and any other crew member working overhead should wear chin straps to keep the hard hat from dropping on personnel below. Also, while working in the mast, crew members should attach their tools securely to the safety belt by means of line. Before ascending, they should clean their shoes of all mud and inspect footholds for grease. No crew member should wear loose or flapping clothes. Gloves should be worn for protection when handling wire rope. Safety shoes with reinforced tops will protect toes from being crushed.

Kelly-Drive Rotary Drilling Operating Principles

The basic components of a *kelly-drive rotary drilling rig* are the derrick and hoist, kelly, turntable, drill pipe, bit, and pump (fig. 9-6).

The drill pipe comes in lengths that are joined together, as the depth of the well increases. The top joint of the drill pipe is connected to the kelly, which is a splined hollow shaft, that passes up through the turntable and kelly bushing. This bushing is grooved to fit the splines on the kelly. When rotated by the turntable, the kelly is free to move up and down. The pump forces a mixture of clay and water through the kelly and drill pipe.

A water swivel, suspended from above, is attached to the top of the kelly. It allows the kelly, drill pipe, and bit to rotate with the driving mechanism. The water swivel and kelly are raised and lowered by a cable that runs from the swivel over the sheave at the top of the derrick down the kelly drum. The kelly drum brakes and wire rope control the pressure and rate of feed to the bit by holding off or applying the weight of the drill pipe.

The accessories of a *kelly-driven rotary drilling rig* include the hoisting plug, slips, drill collar, kelly sub, and casing. The *hoisting plug* (fig. 9-7) is the connecting link between the hoisting line and the drill pipe. It swivels so that the drill pipe is free to turn while being hoisted. The *slips* (fig. 9-8) are used to hold the drill pipe when it is being moved in or out of the hole while a joint is removed or added. The slips are circular wedges made in two or four pieces and fastened together in sets or pairs. Teeth on the inside of each slip grip the outside of the drill pipe. The slips are tapered in such a manner that when set around the drill pipe and pulled into the turntable, they grip the drill pipe securely. The *drill*

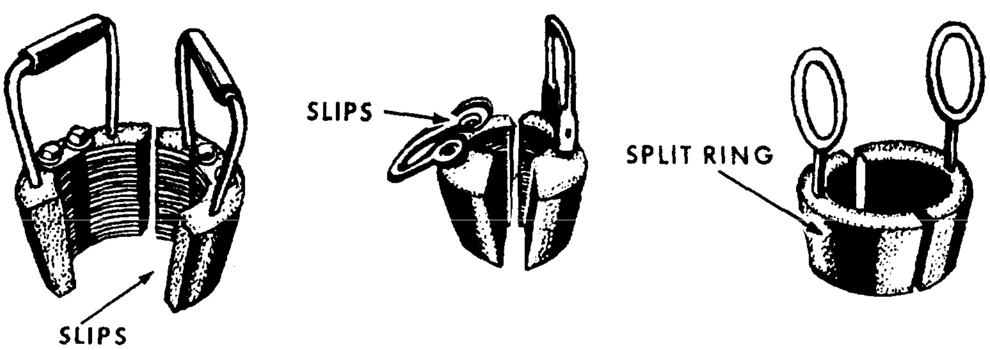


Figure 9-8.—Slips.

collar (fig. 9-9) joins the bits and drill pipe and helps stabilize the bit and keeps the hole uniform and straight. This collar is 10 feet long and has a diameter larger than that of the drill pipe, yet small enough to clear the wall of the hole. The *kelly sub,* or *wear sub,* connects the kelly to the drill pipe. When it becomes worn, it can be changed instead of the entire kelly.

In areas where surface formations are soft or sandy, it is necessary to set the casing to keep the walls of the hole from caving and to prevent the hole from being enlarged by the washing action of the circulating fluid. Sometimes, the hole is reamed or enlarged to set the casing on a firm foundation. To run the casing, you should attach a sub to the hoisting plug and threaded into a length of the casing. Some casings are not threaded and must be welded together. The welded casing can be washed and cooled down by the mixing hose from the mud pump and then run into the hole in the same manner as the drill pipe. If the hole has caved so the casing will not go down, attach the swivel to the casing with a sub and circulate fluid through the casing. This is called washing down and is sometimes used to wash the casing to the bottom of a caving hole.

The kelly and drill pipe are hollow to allow fluid mixtures of clay and water, air, foam, and so forth, to be pumped through them to the bit. The fluid circulates through the drill pipe and out through the bit, where it sweeps under the bit and picks up the material loosened by it. It then carries the material to the surface through the space between the drill pipe and walls of the well. Fluid from the well overflows into a ditch and passes into a settling pit, where the cuttings settle. The fluid free from coarse material and containing only fine-grained clay in suspension, flows into another pit and is picked up by the pump for recirculation in the well.

Enough mud-laden fluid (drilling mud) must be circulated to cool and clean the cutting tool properly and to rise in the hole fast enough to carry the cuttings with it. The weight and viscosity of the fluid, aided by the

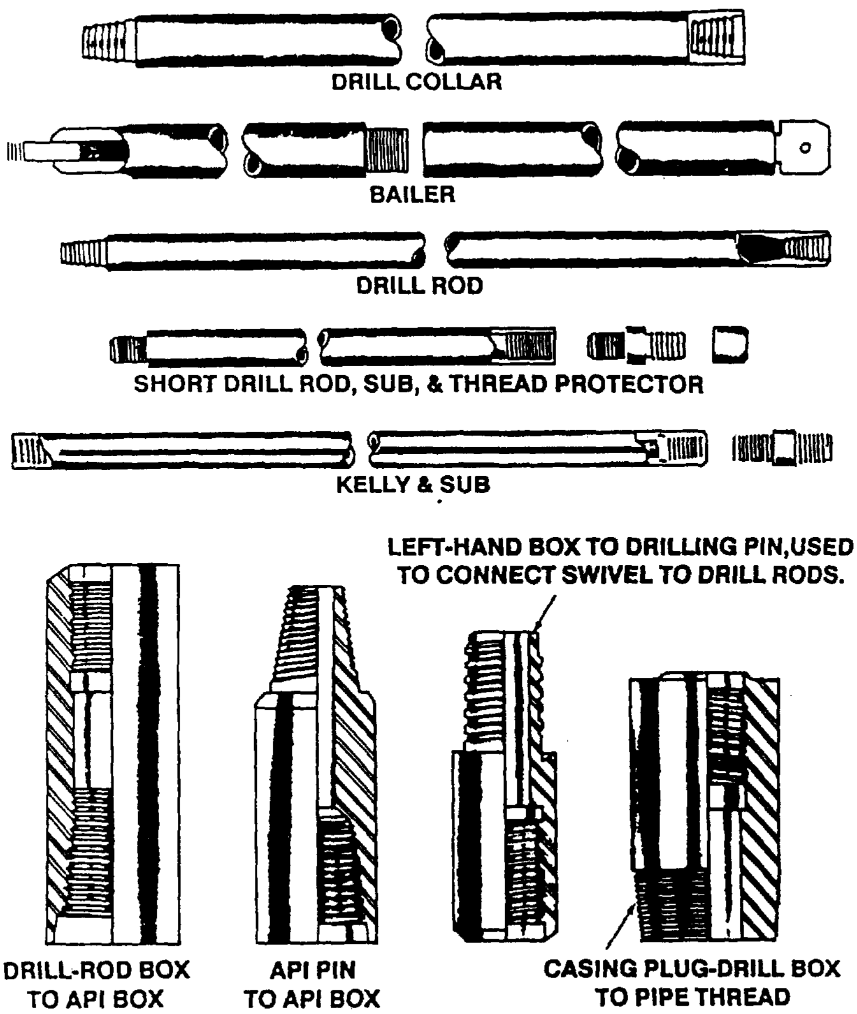


Figure 9-9.-Drill steel, collars, and subs.

plastering action of the fluid spiraling against the wall of the well, prevent the wall from caving-in. The consistency of the mud must permit the cuttings to be held in suspension in the hole, yet permit them to settle out in the surface pits. Although some local clays will mix to an acceptable consistency, many do not. A commercially prepared clay, such as Bentonite, must be added to improve the density of the mud.

Kelly-Drive Rotary Drilling Operations

In well drilling, details of setting up the rig will vary, depending on the rig used. Well drilling rigs can be skid-mounted, trailer-mounted, truck-mounted, or even self-propelled. In any case, it is necessary that the rig is level and cribbed with dunnage before operations begin. Keeping your rig level helps to keep the hole straight during the drilling operation.

While the rig is being leveled, part of the crew can excavate the mud pits (fig. 9-10). The size of the pit depends on the water supply, depth of drilling, and the type of material drilled. A fluid return ditch should be dug from the drilled hole to the settling pit and from the settling pit to the main pit. The ditches enter and leave the settling pit in such a reamer that the flow of fluid is reversed and causes the cuttings to settle, thus keeping them from flowing into the main pit. The pits are lined and sealed with drilling mud and then water is added. Once the mud pits are full of water, the drilling mud can be added and mixed to the right viscosity with the mixing hose. The suction-hose screen is then placed in the main pit at the opposite end of the return ditch. The suction hose is submerged at all times but does not lie on the bottom.

Keep the circulating fluid as clean and free from abrasives as possible to protect the pump parts. The settling pit should be cleaned when 75% full of cuttings so that cuttings will not be placed in circulation. The pit is cleaned when the rig is stopped for a drill pipe change, or drill bit cleaning.

A water supply is essential when drilling wells by the rotary method. There is no set rule as to the amount of water required to drill any one hole. In some cases, where the formations are compact, 3 to 4 gallons of water per foot of hole drilled is sufficient. In other cases where formations are loose and extremely *porous,* a large supply of water is required. For ordinary purposes, 750 to 1,000 gallons of water per 8-hour shift is needed. Skid-mounted and canvas tanks are usually apart of the drilling outfit.

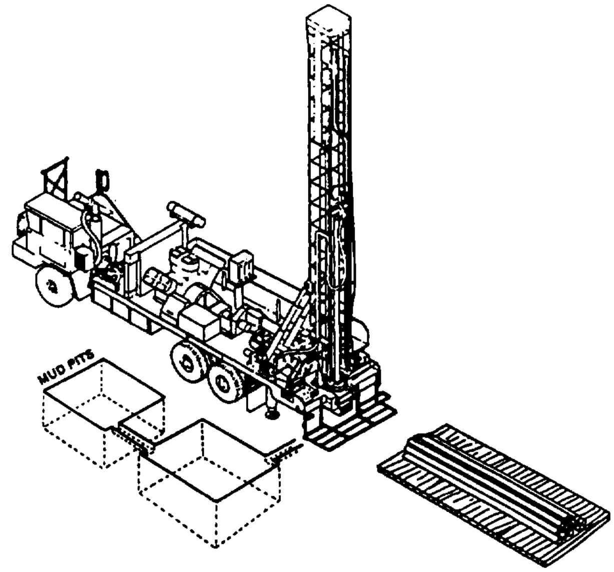


Figure 9-10.-Mud pits.

Even holes spaced only a short distance apart and in the same soil formation may require different drilling techniques. The drill supervisor must be capable of selecting the best bit for penetrating a particular formation. Some examples of *rotary drilling bits* are shown in figure 9-11. Either the *roller* or *the cone type of rock bit* can be used to penetrate moderately hard to hard formations; a *fishtail, three way, or pilot bit* can be used to penetrate soft formations and overburden material.

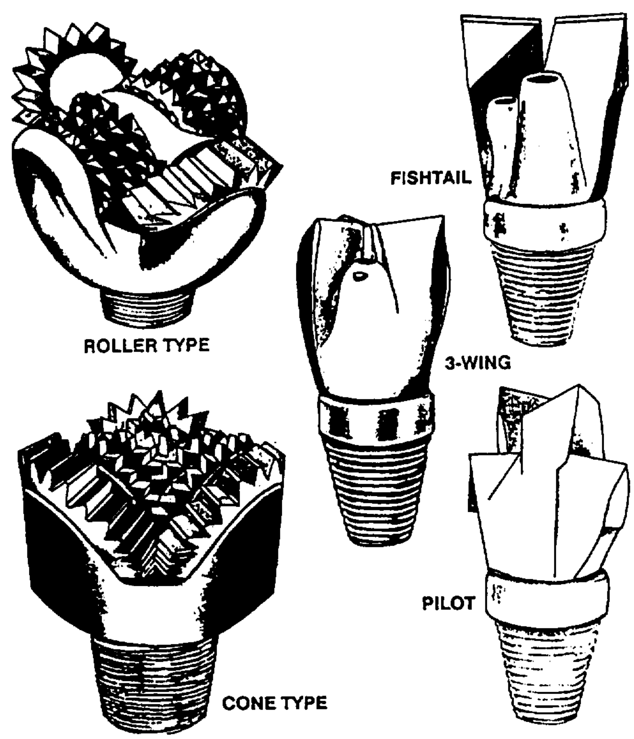


Figure 9-11.-Drill bits.

Before starting to drill with any particular rig, thoroughly read and understand the manufacturer's manual for the machine. Make sure the drilling table, or platform, is clean, dry as possible, and free of loose objects. Doing so will help prevent personal injury and loss of tools down the drill hole. For safety, ensure that the sheave guards remain in place over moving gears and chain drives while the rig is operating. Drillers learn from experience why a well is dug in a certain way and can visualize conditions at the bottom of the hole. No set rules have been established to follow for adjusting speeds of rotation and bit pressures.

In general, you proceed to set up the rig as follows: Move the rig into position on the selected site. Use the hydraulic outriggers to level the rig and take the weight of the rig off the axles. Next, raise the mast and lock it in place. Now check to see that the rig is slightly higher in the rear to allow for settling during the drilling operation.

For *kelly-drive rotary drilling* you continue by doing the following:

1. Run the kelly through the turntable and thread the pilot bit to the kelly.

2. Place the turntable transmission in the proper gear for the soil formation being drilled.

3. Engage the turntable clutch and release the kelly brake slowly to lower the bit into the ground.

4. Engage the mud pump and lower the kelly after the bit has spudded into a depth of 6 to 12 inches.

5. Proceed to drill to the depth of the kelly. Raise the drill bit 6 to 10 inches, circulate to bring all cuttings to the surface, than shut off the mud pump and stop the turntable.

6. Next, raise the kelly until the pilot bit reaches the surface. Remove the pilot bit and lift the kelly clear of the turntable.

7. Move the turntable from its position over the hole. Raise, then lower, a surface casing into the hole, using the hoisting drum. The surfacing casing keeps the well from caving-in from the surface.

8. Once again, position the turntable over the hole.

9. Next raise, then lower, a length of drill pipe into the hole through the turntable, using the hoisting line. The slips will hold the drill pipe in place in the turntable.

10. Follow up by lowering the kelly and attaching it to the drill pipe. To keep these parts from seizing, apply dope on the kelly coupling.

11. Using the kelly drum, raise the kelly and attached drill pipe just enough to enable the slips to be removed.

12. Lower the kelly and drill pipe so the kelly bushing nut slips into the turntable.

13. Engage the turntable and start the mud pump. In doing so, you lower the kelly to drill again.

14. The slips hold the drill pipe in place until the breakout thongs are attached to the kelly. Rotate the turntable slowly until the kelly is unscrewed from the drill pipe.

15. Raise the kelly far enough so another length of drill pipe can be added to the pipe remaining in the hole. Reconnect the kelly and lower into the turntable.

16. Start drilling again until you reach the end of the kelly.

Keep repeating this procedure until you have drilled to the desired depth. You are now ready to complete the drilling operation. Proceed to remove the drill pipe by pulling it out with the hoisting line. Finally, lower the casing with the screen to the desired depth.

If you must change bits before the desired depth is reached, disconnect the kelly and attach the hoisting line to the drill pipe. Pull the drill pipe a length at a time, placing the bottom ends on a board to help keep them clean.

Top-Head Drive Rotary Well Drilling Rig

The *top-head drive rotary well drilling rig* is a special top-head drive ISO/airtransportable water well-drilling rig (ITWD) (fig. 9-12) that the development and production effort was conducted or controlled by NAVFAC towards providing the NCF with the capability for rapid water well drilling in a variety of environments.

The self-propelled ITWD design has a lightweight derrick a telescoping mast, and a top-head rotary drive actuated by hydraulic cylinders able to accommodate 20-foot-long sections of drill pipe and well casings. When the derrick is lowered for transport, the entire rig weighs 23,000 pounds and is capable of fitting inside a standard cargo container without disassembly and is air transportable on board a C-130 aircraft. The ITWD is capable of *rotary drilling* 12 1/4-inch holes to 1,250-foot depths and *down-hole-drilling (DHD) hammer (percussion) drilling,* 6-inch holes to 1,500-foot depths. The ITWD will travel at a top speed

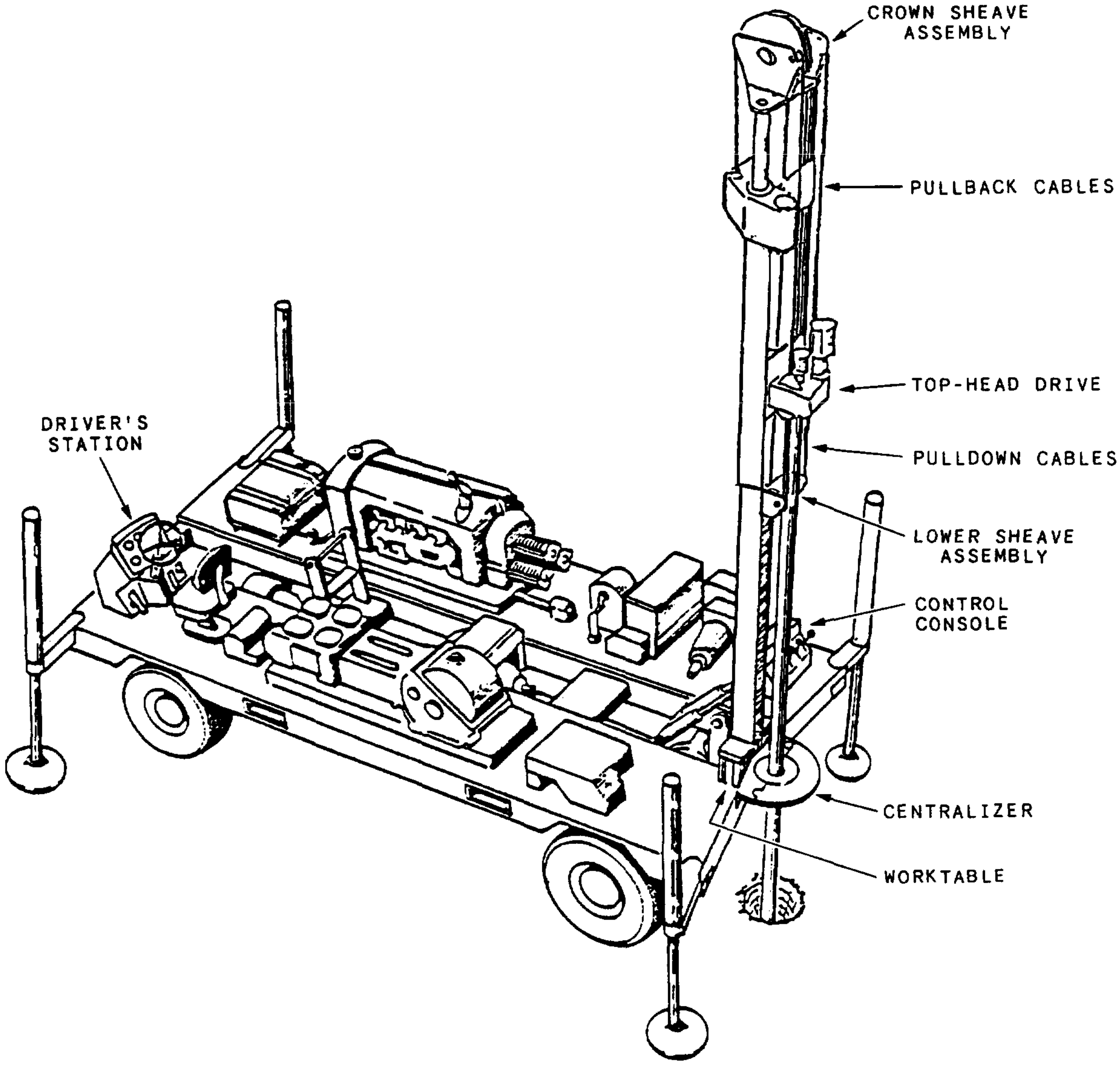


Figure 9-12.-Top-head drive ISO/air-transportable water well drilling rig.

of 10 mph over unpaved roads and has a cross-country rough terrain capability.

ITWD Components

The ITWD derrick consist of the telescoping mast structure, the pulldown/pullback mechanism, the top-head assembly, and the hoist assembly. Other components are a stabilization system, main frame, handling equipment, hydraulics, control console, and so forth.

The drill derrick system is capable of generating 15,000 pounds pulldown and 30,000 pounds pullback force through the top-head during the drilling operation. The top-head drive is a variable speed drive that imparts rotation and torque to the drill pipe for drilling and has an rpm range from 0 to 200 rpm. The tophead drive is mounted to a carriage that is free to move up and down over the length of the moving mast section. The tophead drive also has a hollow spindle for injection of air or mud, giving the ITWD capabilities for *rotary air* or *rotary mud drilling.*

The hoist system is attached to the side of the derrick and operates independently of the derrick operation and is rated for a 3,000-pound hook loading. This capacity is sufficient to add and remove 18.5-foot drill pipes and to set typical 20-foot casing and surface pipe. The hoist is capable of lifting up to 180 feet of 4 1/2-inch drill pipe when “tripping out” the drill hole. When increased hoisting is required for lifting longer drill strings, the top-head drive that has a capacity equivalent to its

30,000 pullback rating can be used as an additional hoist.

A split centralizer and pipe-handling system located on the ITWD worktable is used to break and make drill pipe connections, to support the drill string during pipe handling, to provide a centralizer bushing for the drill string, and to aid in setting casing and making casing joint. The centralizer is a split design consisting of a rear section welded to the main frame and a removable forward section. The forward section is held in place by two pins and can be manually swung out or detached to facilitate setting large diameter casing or surface pipe. The forward section is removed during transport and stored on top of the worktable. The centralizer accommodates various sizes of split bushings to adapt to a number of drill pipe, casing, and down-hole-drilling hammer diameters.

A hydraulically powered breakout wrench is also mounted on the worktable. This wrench is used with a manual holding wrench (used to support the drill string and stop rotation) to make and break pipe and casing joints.

Top-Head Drilling Operations

All personnel assigned to drill with the ITWD should thoroughly read and understand the operator's manual before proceeding with any drilling operations. Additionally, **SAFETY IS PARAMOUNT** over all actions performed during drilling operations.

In general, you proceed to set up the rig as follows: Move the rig into position on the selected site. Use the hydraulic outriggers to level the rig and take the weight of the rig off the axles. Ensure adequate overhead clearance; then raise and lock the derrick.

For the *top-head drilling rig* proceed with the following:

1. Attach the centralizer half to the worktable.

2. Install the centralizer bushings.

3. Place the bottom holding wrench in position.

4. Dope (lubricant for threads) the top-head spindle sub threads.

5. Lower the hoist and attach the hoist plug.

6. Raise the top-head.

7. Dope the tri-cone bit threads (down-hole-drilling hammer treads if hammer drilling).

8. Manually thread the bit into the bit sub.

9. Wrap the mud flinger around the bit sub.

10. Dope the hoist plug threads and thread into the bit sub.

11. Raise the bit sub with the hoist and insert into the centralizer bushing.

12. Insert the holding wrench to the support bit sub; close the forward half of the centralizer and pin it shut.

13. Remove the hoist plug from the bit sub.

Installation of the Drill Pipe:

1. Slide the drill pipe sling over the drill pipe.

2. Attach the hoist cable to the drill pipe sling and hoist the drill pipe into position over the bit sub.

3. Lower the top-head into position with the rotation on slow.

4. Tighten all connections and raise the drill slightly off the holding wrench and remove the holding wrench.

Rotary Mud Drilling:

1. The mud pits for top-head drilling are dug and designed, as shown in figure 9-10.

2. Connect the suction hose to the mud standpipe.

3. Place the suction hose into the mud pit and connect the hose to the mud pump inlet.

4. Set the engine speed to the manufacturer's recommendations and open the mud pump valve.

5. Control the mud flow by adjusting the mud pump speed.

6. While drilling, adjust the top-head drive spindle rotation and pulldown speed and monitor the mud pump stand pressure to avoid a plugged drill bit or loss of pump prime.

7. Upon completion of the hole, place the suction hose in a source of clean water and flush the drill pipes and bit.

Rotary Air Drilling:

1. Lower the bit to within 4 inches of the ground, and connect the flushing line to the air compressor.

2. Turn on the compressor, open the air valve, and set the engine speed at the speed recommended by the manufacturer.

3. Set the pulldown regulator to a minimum and start the top-head drive spindle rotation, and set the pulldown speed to LOW.

4. Monitor the pulldown and top-head drive spindle rotation pressure gauges to avoid overthrust and monitor the air line pressure to avoid a plugged bit.

5. When the drill hole is complete, shut down the air and repressurize before "tripping out" the hole.

Down-Hole-Drilling (DHD) (fig. 9-4):

1. Use the percussion button bit.

2. Use the holdback regulator to control feed forces.

3. Switch on the DHD line oiler before operating the DHD. (A air line lubrication system injects a determined rate of oil into the flushing hose to lubricate the DHD hammer when air hammer drilling.)

4. Use the DHD line oiler regulator to adjust the oil flow and check the oil flow by placing a piece of cardboard under the spindle sub and inspect the pattern.

5. Monitor the DHD frequency and cuttings to determine proper feed force.

Setting Casing:

1. Retract the top-head drive and unpin and swing out the forward centralizer.

2. Replace the centralizer bushing with casing clamps.

3. Install the choker sling on the first casing, and hoist the casing above the drilled hole.

4. Lower the casing into the hole until the top is about 1 foot above the worktable.

5. Close the centralizer and pin it shut.

6. Remove the choker sling and attach it to the next casing. Hoist the second casing above the first.

7. If the casing is plastic, install the collar and cement joint. If weld type, join shoulders and weld. And if thread type, clean threads and dope and tighten with a chain wrench or breakout wrench.

8. Set the screen and rest of casing.

9. Unpin and swing out centralizer.

10. Gravel pack and grout as to the construction specifications.

DRILLING DIFFICULTIES

Lost circulation is one difficulty you may encounter when drilling. Sometimes it occurs in zones of *high porosity* that usually contain large supplies of water. A test of the well should be made whenever circulation is lost. Formations that draw off or absorb all or part of the circulating fluid offer problems, ranging from minor inconveniences and loss of time to extreme conditions that render rotary drilling impossible.

Formations that contain joints and fissures, such as quartzite, sandstone, limestone, and dolomite, present problems arising from caving, abrasion, and complete loss of circulation.

Shale that is jointed and fissured seldom draws off an excessive amount of circulating mud; however, drilling fluid that is absorbed causes the shale to swell and heave, filling up the drill hole. This has been overcome by the use of special drilling fluids. 'This condition is rare, and satisfactory drilling progress can usually be made by using a drilling fluid of high viscosity and weight.

Sands and gravel often absorb enough drilling fluid to hinder drilling progress. Fluid loss, which, in most cases, will be continuous, should be replaced with mud, not water. Water, when used to maintain sufficient volume for circulation, soon lowers the viscosity and weight of the mud-water mixture, and caving results.

Two methods are used to regain lost circulation. The preferred method is to drill through the zone of lost circulation and to set a string of *conductor casings* below the *porous zone.* The chief requirement for this procedure is a plentiful supply of water to circulate the cuttings away from the bit and into the formation. Mud is desirable but the quantity needed usually precludes its use. When using water to carry off the drill cuttings, always remember to continue to operate the pump for a few minutes after drilling has stopped. This flushes the cuttings out of the hole and prevents the drill pipe from sticking when it is stopped to make a connection. In extreme cases where it is necessary to drill as much as 100 feet or more through a formation in which circulation is lost, a small quantity of mud is spotted around and above the bit while an additional joint of pipe is installed in the drilling string. This prevents excessive settling of the drill cuttings and consequent sticking while the drill pipe is standing. When the bottom of the zone has been reached, drilling is continued into the underlying formation for about 50 feet to give room for cementing the casing. When the casing has been run and cemented, the ordinary rotary drilling procedure is resumed.

In the second method, circulation can usually be regained by mixing a clay-type material with the drilling fluid that can be bought commercially. The water well drilling school located at NCTC, Port Hueneme, uses the second method when circulation is lost during drilling operations; however, to regain circulation the school recommends dropping into the hole approximately a yard of 3/4-inch to 1-inch clean aggregate to regain circulation. The amount of clean aggregate used depends on the size of the area in which circulation is lost. If circulation is lost in cavernous limestone, the fluid level in the hole is checked and tested for fresh water.

A cheap, abundant supply of water is often the determining factor between a straight well hole and a loss of time, labor, and equipment.

Much depends on the experience and ability of the driller when drilling through difficult formations. The driller will have to use the capabilities of the machine and experience to keep the hole straight. The harder formations, especially those which are dipped and those that are broken and crevice, present many difficulties. Use only a roller and *three- or four-wing drag bits* for this type of drilling. *Fishtail* and some of the *single-cone roller bits* are not suitable for any except the softest formations.

Crooked Holes

One way to detect crooked holes during drilling is to watch for wear on the drill pipe. If wear occurs at a set distance from the top of the ground, it indicates the hole was deflected at this point. When drilling, detection of deflections of the bit and drill pipe is not easy because the hole can be quite crooked without noticeably affecting the operation of the rig. The driller must be alert to any indication that the hole is going crooked.

To avoid crooked holes, make sure that the bits are of a form and size that prevent undue eccentricity during rotation. They must be sharp and dressed to proper gauge. The drill collar that holds the bit to the lower end of the drill pipe must be large enough in diameter to hold the pipe centrally in the hole and to prevent the bit from working off to one side. Avoid excessive bit pressures.

Another difficulty sometimes encountered is the sticking or freezing of the drill pipe. An inexperienced drill operator can cause the drill pipe to stick by not circulating mud in the hole. The drill pipe is kept free in the hole by simultaneously rotating the pipe and circulating a mud-laden fluid. If either operation stops, only a short time should elapse, depending upon the formation being penetrated before pulling the bit into the casing (or out of the hole altogether, if no casing has been installed). Failure to do this often causes the drill pipe to become stuck due to sand and cuttings settling around it.

The drill pipe may also stick in some formations if lost mud is replaced with water and not mud. Formations are often encountered that drain off or absorb a certain amount of the drilling mud. If this mud is replaced with clear water to keep up the fluid level in the hole, the water thins the mud to a point where the mud exerts a cutting action on the walls of the hole and causes extensive caving around the drill pipe, fastening it securely in the hole.

Inadequate equipment may cause the drill pipe to stick; for example, a mud pump with insufficient capacity would not keep circulation moving fast enough to prevent drill cuttings from settling out and jamming the drill pipe.

Balling up may also cause the drill pipe to stick. *Balling up* is the accumulation of soft, sticky shale or clay around the drill collar and bit. Occasionally, mud collars are formed that are forced up the hole by the pump action. This balling, if allowed to continue, forms a coating around the drill collar that sticks to the drill pipe securely when it is raised off the bottom. The usual cause of balling up is a high rate of penetration, combined with a speed of rotation insufficient to mix the drill cuttings thoroughly. To overcome these conditions, the drill operator should raise the pipe frequently by raising it off the bottom 4 or 5 feet and then drop the pipe while it is rotating rapidly. If this is done and if the rate of penetration is held to a speed that gives the circulating fluid time to mix the drill cuttings thoroughly, this source of trouble can be held to a minimum.

As mentioned before, loss of circulation may result in a stuck drill pipe. Loss of circulation is especially troublesome in *porous limestone* that contains much water. When one of these *porous zones* is penetrated by the drill, the pressure of the drilling mud causes it to drain off rapidly into the formation. The sudden reversal of circulation in the hole deposits the suspended drill cuttings around the drill pipe. This often happens so suddenly that there is no time to remove the drill pipe.

Recovery of Stuck Drill Pipe

Every precaution should be observed to prevent the drill pipe from sticking as only extreme scarcity of drill pipe justifies extensive recovery operations in drilling shallow wells; however, there are a few things that can be done successfully with the equipment at hand, depending upon how tightly and in what manner the drill pipe is stuck.

When the drill pipe becomes stuck by *balling up* while drilling in soft shale or clay, it can often be loosened by circulating clear water. An upward strain should be kept on the pipe while circulating the water.

When the pipe is stuck by sand or drill cuttings that have accumulated in the hole, circulation should be maintained with the heaviest mud obtainable. When possible, the pipe should be worked. Any movement transmitted through the pipe, however slight, helps dislodge the sand particles into the mud stream that carries them to the surface.

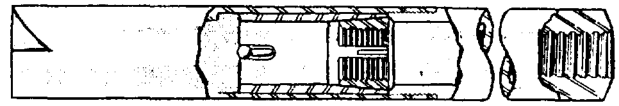
When a drill pipe is stuck through lack of circulation, there is not much that can be done to recover the entire string of pipe; however, an attempt should be made to pull the pipe with jacks. Sometimes the pipe can be recovered by mixing the proper circulating fluid and circulating it while working the pipe with both the rotating and hoisting mechanisms. In some instances, the pipe can also be recovered by cutting it with a blasting charge in the bottom of the hole or about where the pipe is stuck.

Fishing

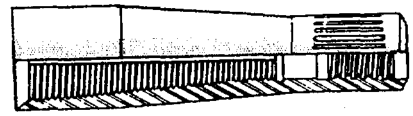
One of the major problems encountered when well drilling is the recovery of tools lost in the well. Lost tools are recovered by fishing. The most frequent cause of tool loss in rotary drilling results from the drill pipe twisting off. Such "twist offs" usually occur near the lower end of the pipe. They may consist of a simple shearing off from the pipe or of a fracture at a coupling. The accidental dropping of a drill pipe into a hole also calls for fishing. Among less common accidents requiring fishing is the dropping of tools, such as slips or wrenches, into the hole. When a break occurs, remember the exact depth of the break. This helps in locating the tops of the tools and coupling to them with a fishing tool. Recovery of lost drill pipes depends upon whether the driller can set the tool down on top of the pipes and connect to them.

Some of the more common fishing tools are the *circulating-slip overshot,* the *die overshot,* and the *tapered fishing tap* (fig. 9-13).

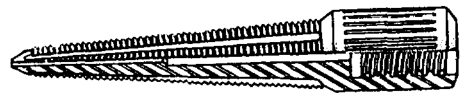
The *circulating-slip overshot,* as implied by its name, provides circulation through the lost pipe to assist removal when fishing. This tool is similar to the die overshot in its action but provides a watertight coupling between the drill pipes.



CIRCULATING-SLIP OVERSHOT



DIE OVERSHOT



TAPERED TAP

Figure 9-13.-Tap and overshot fishing tools.

The *die overshot* is a long-tapered die of heat-treated steel. When fitted over the lost drill pipe and rotated, the die overshot, like the fishing tap, also cuts its own threads. The tapered thread is fluted to permit the escape of metal cut by the threads. The upper end of the die has a thread to fit the drill pipe. The die is hollow but, as is also true of the tap die, circulation cannot be completed to the bottom of the hole through the lost pipes because the flutes allow the fluid to escape.

The *tapered fishing tap,* as its name implies, is a fluted tapered tap made of a heat-treated steel. Its action is similar to that of a machine tap, as it cuts its own threads when rotated, and thus grips the lost drill pipe.

REMEMBER: In many shallow wells, it is more economical to abandon the hole than it is to fish for the lost tools.

WELL DEVELOPMENT AND COMPLETION

Once an aquifer has been tapped by the drilled hole, the important and essential phase of completion and development must be accomplished in order to assure maximum yield under sanitary conditions. Development and completion of a well includes

1. setting the casing and screens,
2. removal of the drilling fluid, and
3. stabilization of the aquifer by removal of a predetermined percentage of the fines, grouting, and sterilization of the well.

The first operation after drilling the hole (fig. 9-14) is to set the screens and casing (fig. 9-15). The casing prevents collapse of the drilled hole walls in unconsolidated formations. The screens prevent collapse of the drilled hole wall in the aquifer while allowing water to enter the casing freely. After the casing is set, the well is gravel-packed (fig. 9-16). Gravel packing is placing graded aggregate on the outside of the casing to allow for more production and prevent "fines" from entering the well pump, tanks, and systems.

When the screens, casing, and gravel pack have been completed, the well is ready for development. Development is accomplished by removing the drilling fluid from the aquifer and the employment of any means that induces an alternating flow of water in and out through the screens. This action stirs up the unconsolidated material in the aquifer and allows removal of the finer particles. Gradually, the coarsest particles become stabilized around the screens, and the last vestiges of drilling fluid are removed, permitting the well to yield its maximum capacity.

A variety of methods are used for setting screens, removing drilling fluid, and developing aquifers. The method used for either of these operations is often determined by the tools and equipment available.

When development of a well is complete, it is required to grout as a sanitary protective measure to prevent seepage of surface water or contaminated water from water-bearing formations above into the aquifer. Grouting is accomplished by cementing from the top of the gravel pack to the annular space between the well wall and casing (fig. 9-17).

WELL DRILLING SAFETY

Safety is paramount in all construction operations. You must always be safety conscious and on the alert for potential dangers to personnel and equipment. Safety considerations cannot be overemphasized.

1. Hard hats area must and should always be worn.

2. Gloves should be worn to protect hands when handling wire rope.

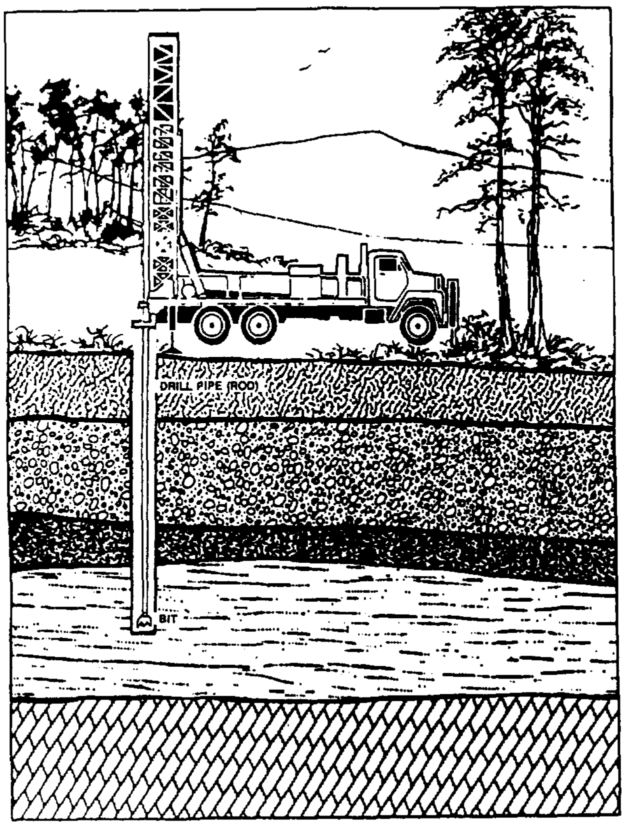


Figure 9-14.-Drilling the hole.

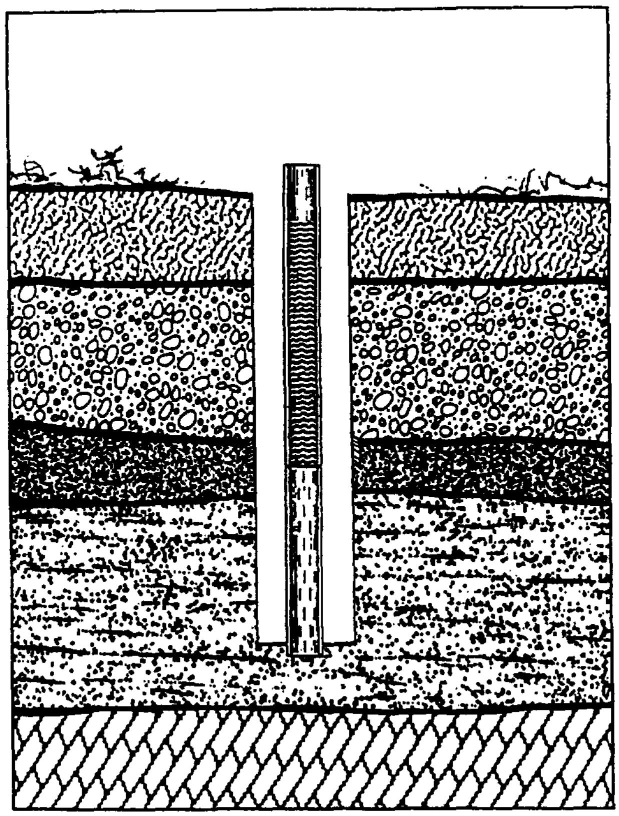


Figure 9-15.-Casing the hole.

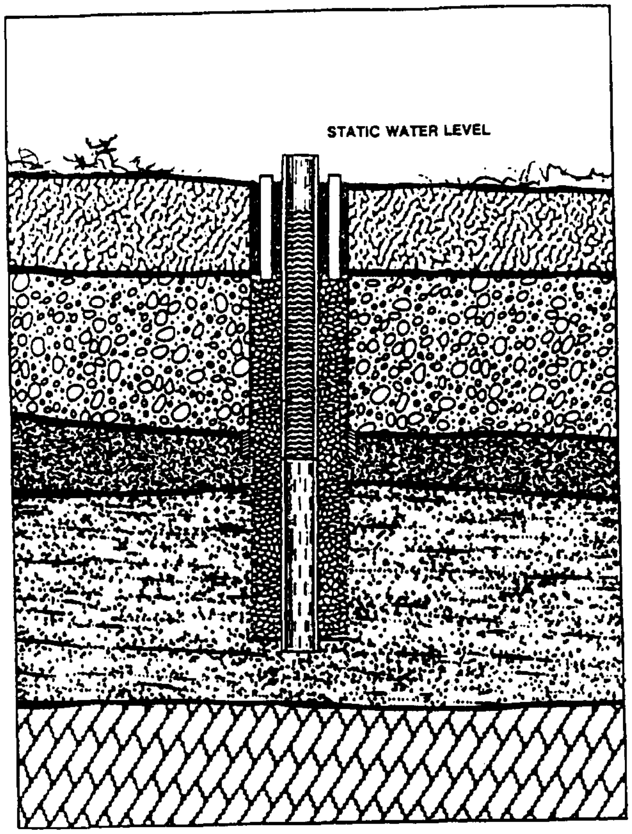


Figure 9-16.-Gravel pack.

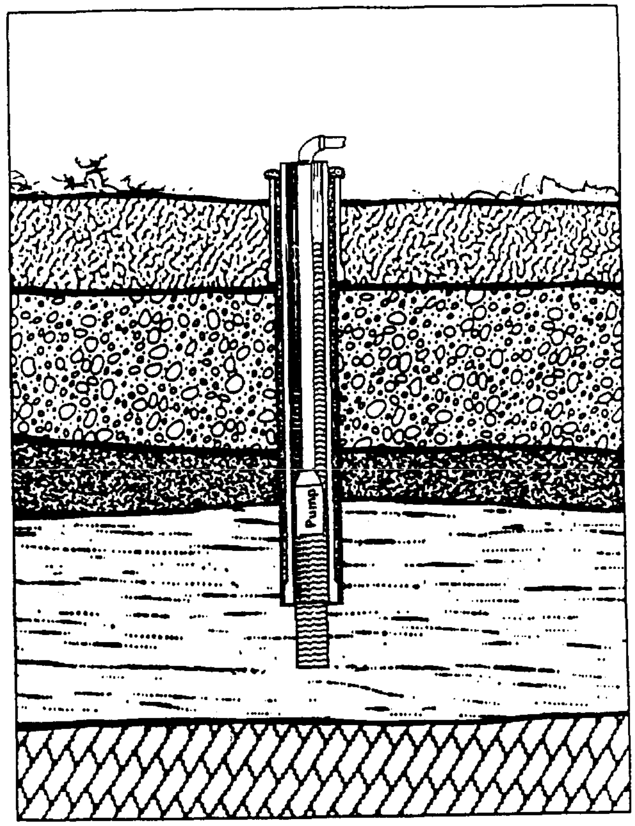


Figure 9-17.-Capped well.

3. When working in the mast, safety belts should be worn, and tools should be securely attached to the belts by lines.

4. Before ascending, safety shoes should be cleaned of all mud and footholds inspected for grease. Wearing of safety shoes with reinforced tops will protect toes from being crushed when working with drilling tools.

5. Sheave guards should remain over all moving gears and chain drives.

6. Personnel should not wear loose or flapping clothes.

7. The drilling table, or platform, should be kept free of loose tools, both to prevent accidents to personnel and loss of tools down the drilled hole. The platform should also be kept clean and dry as possible.

8. Do not attempt to lube or adjust moving gears.

9. When hoisting loads, do not place yourself between any moving part and stationary object.

10. Stay clear of suspended loads.

11. Repair or replace all parts that need repair as needed.